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# *GAULTHERIA PROCUMBENS* AT PINE HILLS, INDIANA—ITS CONTINUED DECLINE AND INCIPIENT EXTIRPATION, 1951–1981

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## ABSTRACT

Wintergreen, *Gaultheria procumbens,* a perennial evergreen member of the boreal forest, has persisted as a post-glacial relic on an acidic, south-facing slope at Pine Hills, Montgomery County, Indiana. The population area is believed to have been minimal in 1868 when overlying hemlock was cut. Surveys in 1951, 1961, 1971, and 1981 have shown the colonies to have expanded vigorously until 1961, then to have undergone a precipitous collapse, associated with regrowth of the hemlock, and to have now approached local extinction. An effort to reverse the population decline by removal of a portion of the hemlock overstory appears not to have been successful.

Key Words: *Gaultheria procumbens, Tsuga canadensis,* glacial relic, extinction, Pine Hills, Indiana

## INTRODUCTION

In the centuries following the Glacial Maximum, 18,000 Y.B.P., the zones of vegetation forced southward by the advance of the ice returned northward, each in turn overriding and displacing the more cold-resistant floras, but occasionally leaving pockets of boreal species in favorable niches.

*Gaultheria procumbens* L., or wintergreen, was one of the species so isolated (Friesner, 1937). In Indiana it has survived in only five counties south of the northern third of the state (Deam, 1940). In the first discovered (Coulter, 1900) and most carefully monitored (Ward, 1976) of these stations, a population in the Pine Hills Natural Area of Montgomery County, the species has been observed over a recent 30 year period to have undergone a rapid decline in numbers and vigor, and to have now approached local extinction. The previous local abundance of wintergreen is thought to be a result of removal of the hemlock overstory in 1868, and its recent near-disappearance is believed caused by forest regrowth.

This study continues a project begun in 1951 of surveying and mapping *Gaultheria* as it occurs in the Pine Hills area, to deter-

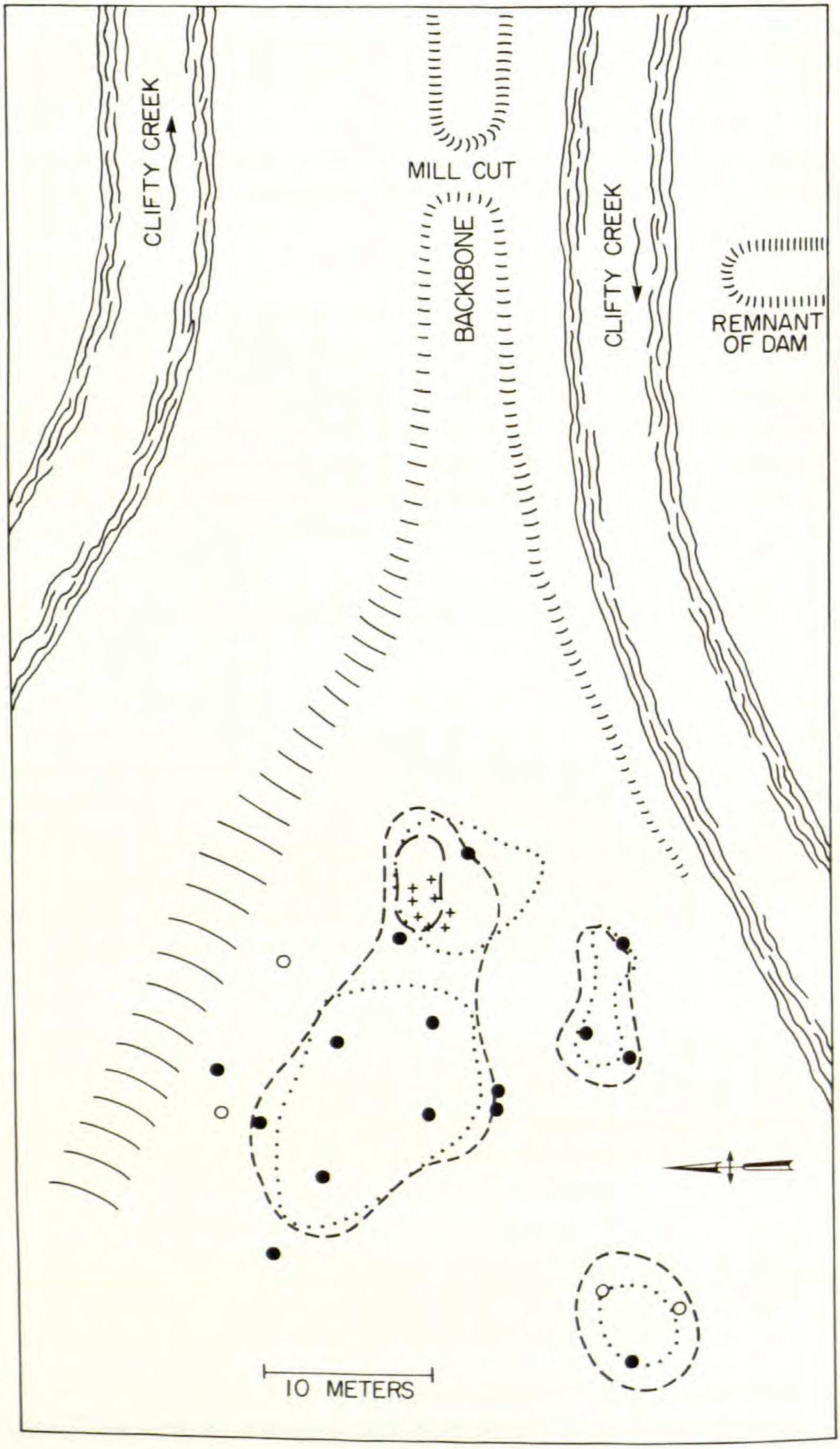
mine the factors affecting its survival and decline. The present paper recapitulates the observations and interpretations obtained by surveys in 1951, 1961, and 1971 (Ward, 1976), and extends these observations to include a survey conducted in 1981 and subsequent efforts to preserve the population.

## THE PINE HILLS AREA

The Pine Hills Natural Area, in southwestern Montgomery County, Indiana, is an oft-studied region of steep cliffs, cool north-facing slopes, and well-leached acid ridges. The physiography has been described by Smith (1933), the vegetation has been mapped by Friesner and Potzger (1934), the soil acidity and its relation to hemlock reproduction has been examined by Potzger and Friesner (1937), and the flora has been inventoried by McCormick (1962). Its significance as a natural area is such that it was appropriately given a rating of "1" by Lindsey et al. (1969). By the happenstance of prolonged single-family ownership and pride in its natural features, the Pine Hills central area survived without significant disturbance until funds were available for completion of its purchase by The Nature Conservancy in 1960 (McCormick, 1962). It is now assigned for maintenance in perpetuity as a wilderness area by the State of Indiana, administered by the Indiana Department of Natural Resources.

Pine Hills is most noted for an impressive series of incised meanders of Indian Creek and its subsidiary Clifty Creek, tributaries of Sugar Creek, the principal drainage channel of the region. During the Pleistocene glacial cycles, morainal deposition displaced Sugar Creek from its original channel and forced it into a new alignment closer to the headwaters of Indian and Clifty Creeks, thus steepening the gradient of these lateral streams. Subsequent erosion of the underlying sandstones has deeply entrenched both Sugar Creek and its tributaries, while retaining the meandering course that these secondary streams had established in the mature pre-glacial topography.

At seven places in the Pine Hills area these streams bend back upon themselves, or upon each other, to form steep-sided ridges or "backbones" up to 70 m long and 33 m above the stream beds (Smith, 1933). The backbone known as "Mill Cut" is formed by a looping bend of Clifty Creek. This stream in its headwaters


CLIFTY CREEK
MILL CUT
BACKBONE
CLIFTY CREEK
REMNANT
OF DAM
10 METERS

flows generally northward, abruptly changes direction to the west, circles widely to the north and east, and approaches the course of its westward channel before again turning sharply northward, eventually to join Indian Creek (Figure 1). The westward and eastward legs of the stream thus flow in opposite directions but in close proximity, separated by a sheer two-faced wall of Borden sandstone.

This wall, the Mill Cut Backbone, has been formed in the same manner as the other backbones of the Pine Hills region (Smith, 1933). The Borden deposits, of Middle Mississippian age, are subject to frost action parallel to the exposure surface and independent of the essentially horizontal bedding planes, the rock spalling off in great flakes up to a meter or more in width. The erosive effect of repeated freeze-and-spall, with the debris periodically removed by streamflow storm surges, has produced a channel that varies in depth from 9 or 10 m at the lowest point of the backbone to over 20 m at the east end where the backbone merges with the adjacent upland.

The history of human activity in the vicinity of the backbone has been recovered in part by McCormick (1962) from historic papers and census records. A contract was signed December 4, 1868 permitting the construction of a dam on Clifty Creek for the purpose of supplying water power to machinery, and the enterprise was incorporated as the Pine Hill Woolen Mill Company. In the winter of 1868–69, a rough roadway was graded down the ravine slope of Clifty Creek to the south of the backbone and a log crib and rock-rubble dam 4.6 m high was constructed across the stream. The cribbing of this dam was primarily of hemlock logs cut from the adjacent south-facing slope, immediately west of the backbone. A square-bottomed notch or "millcut," about

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Figure 1. Map showing Mill Cut Backbone, Pine Hills, Indiana, and associated colonies of *Gaultheria procumbens*. Clifty Creek flows from upper right, downward along the south face of the backbone, then circles widely (off the plate) to reappear on the north face of the backbone. Within this loop of Clifty Creek a knoll (indicated by hatch lines) extends eastward to a cut where a millrace was located in 1868. The dam which once blocked the stream remains only as a low mound of rock rubble. Major trees are indicated by large dots (with those dead since 1951 represented by hollow dots). The colonies of *Gaultheria* present in 1951 are represented by perimeters of small dots, those in 1961 by short dashes, and those in 1971 by long dashes. Plants surviving in 1981 are shown by crosses (+).

6 m deep and 3 m wide, reaching to within 3 m of the bed of the west-flowing channel, was cut through the narrowest and lowest portion of the backbone, and a wooden flume from the north side of the notch carried the impounded waters about 50 m to an overshot waterwheel at a small, 208 spindle woolen mill that was located on the terrace of Clifty Creek to the north of the backbone.

Perhaps because of the unstable and often destructive force of the stream, in 1873 one of the original investors built a new, larger mill on Sugar Creek below the mouth of Indian Creek (Kennedy, 1881), and the small mill on Clifty Creek was abandoned. Today only a low mound outlining the southern end of the dam, a remnant of the access road, and the prominent millcut, give an overt indication of this brief industrial activity. Yet the changes observed over recent decades in the area covered by wintergreen on the knoll at the west end of the backbone can be explained only as collateral consequences of this human disturbance more than a century ago.

In historic times, *Gaultheria procumbens* in the Pine Hills region has been known only on the knoll encircled by the loop of Clifty Creek as it swings from the south to the north side of the Mill Cut Backbone (Figure 1). As the creek entrenched itself in the Borden formation it swung ever wider in the westward portion of its bend, leaving an elevated rise surrounded on the south, west, and north by the stream and connected to the upland to the east only by the narrow ridge of the backbone. Through time, the circumneutral glacial overburden of this knoll was removed by erosion, leaving a thin acidic soil derived from the parent Borden sandstone. The surface of the knoll slopes downward to the south, smoothly merging with a narrow bench just above the west-flowing leg of the stream. It is on this gradual south-facing slope that *Gaultheria,* following its post-Pleistocene re-establishment in north-central Indiana, has long persisted.

## PREVIOUS STUDIES

The Mill Cut Backbone stand of wintergreen has been known to the writer since his boyhood in the early 1940's while on recreational outings and field trips with Dr. Albert R. Bechtel, professor of botany at Wabash College and a family friend. In those early years the Mill Cut knoll was an open, well-lit slope,

free of significant undergrowth, and the *Gaultheria* was conspicuous as dense, sharply defined, evergreen carpets. Tiny hemlock seedlings protruded here and there, adding charm to the scene and in no way suggesting the devastation to the wintergreen that their continued growth would ultimately bring.

In 1951, the writer, then in graduate school and aware of the relic importance of the *Gaultheria* stand, began a series of periodic plant surveys of the Mill Cut knoll. The observations made in 1951, 1961, and 1971 were summarized and published in 1976 (Ward, 1976).

In August, 1981, a fourth decennial survey was conducted. As in the previous surveys, the larger trees on the site were used as reference points, thus permitting precise location of the surviving *Gaultheria*.

## RESULTS

The vegetation of the *Gaultheria* slope and its changes over the first twenty years of this study have been described in some detail (Ward, 1976). The slope was originally sparsely covered with mature trees. Toward the crest, northern red oak (*Quercus rubra* L.), black oak (*Q. velutina* Lam.), and a few large hemlocks (*Tsuga canadensis* (L.) Carr.) were predominant, while lower on the slope white oak (*Q. alba* L.) and white pine (*Pinus strobus* L.) appeared. The understory near the crest was formed of black gum (*Nyssa sylvatica* Marsh.), flowering dogwood (*Cornus florida* L.), red cedar (*Juniperus virginiana* L.), witchhazel (*Hamamelis virginiana* L.), and wild hydrangea (*Hydrangea arborescens* L.). These were replaced lower on the slope by shadblow (*Amelanchier arborea* (Michx. f.) Fern.), ironwood (*Ostrya virginiana* (Mill.) K. Koch), red maple (*Acer rubrum* L.), mapleleaf viburnum (*Viburnum acerifolium* L.), sassafras (*Sassafras albidum* (Nutt.) Nees), partridgeberry (*Mitchella repens* L.), and running euonymus (*Euonymus obovatus* Nutt.). Wintergreen (*Gaultheria procumbens*) was restricted to this slope, below the crest and above the stream bench of Clifty Creek, where it formed dense mats or colonies of low, perennial, vegetatively reproducing, woody stems.

The appearance of the *Gaultheria* slope had changed markedly during the first 20 years it was under observation (Ward, 1976). In 1951 the area was sunny and open, but to some extent by 1961

and conspicuously by 1971 had become thickly covered with sapling hemlocks plus a smaller number of young white pines. By the fourth decennial survey, in 1981, these young trees were 3–6 m tall with basal diameters ca. 5 cm. All lower branches were dead, as were many of the smaller trees, a probable consequence of crowding and shading. In most parts of the area there was little opportunity for the lower vegetation layers to receive direct sunlight, while in the more open places perhaps 5–15% of the ground surface was lit by the noonday sun.

The area covered by *Gaultheria* in the four decennial surveys documents the initial expansion and subsequent collapse of the population. The 1951 observations recorded wintergreen in four distinct and sharply demarked colonies (Figure 1). These ranged in area from 16 $m^2$ to 130 $m^2$, and together covered 204 $m^2$. An estimated 100 stems/$m^2$ were present in most areas. By 1961 each of the four colonies was slightly enlarged, two of them having met and become one, with a total area of 307 $m^2$. The maximum distance *Gaultheria* was found outside the 1951 perimeter was approximately 150 cm, suggesting an average annual rate of spread of 10 to 15 cm. Although the colonies remained vigorous, their future decline was adumbrated by a reduced density with no areas appearing to exceed 80 stems/$m^2$ and small portions supporting few or no plants. By 1971 the colonies had lost their discrete outlines. One of the colonies no longer existed, a second was represented by two plants, while the formerly merged colony was reduced to 16.3 $m^2$, containing no more than 5 to 10 leaf-bearing stems/$m^2$, plus some 21 scattered, single-stemmed plants.

By 1981 the wintergreen had very nearly disappeared. Initially only two plants were found, but on a subsequent inspection a total of 8 plants was located, all in or near the area that had been most densely covered at the time of the previous survey. Each plant was represented by a single upright stem. The typical *Gaultheria* pattern of alternate leaves in which three or four adjacent nodes are suppressed, thus giving the appearance of annual whorls, had given way to two pairs of leaves, the upper pair much smaller than the two formed the previous season.

These changes in population size and vigor were measured in the four decennial surveys by careful mapping and calculation of the area covered, by counts of individual, isolated plants, and by estimates of the number of stems/$m^2$. This last measure, of stem density, is unquestionably of importance in measuring the vigor

of the colony and may serve well as a harbinger of future population expansions or declines, but is not retrospectively quantifiable. Thus, area covered by the population, supplemented by token values given to remnant fragments, seems to provide the best available measure of population size.

In addition to the values obtained in the four decennial surveys from 1951 through 1981, a population estimate is available for 1868, when the *Gaultheria* slope was logged and light intensity at the understory level was increased. Since the vigorous growth observed between 1951 and 1961 could not have been of long duration without having completely covered the Mill Cut knoll, the four colonies initially observed may have been derived from as few as four plants surviving when the overlying timber was removed in 1868. No reproduction by seed was observed, either within the perimeter of the colonies or elsewhere on the knoll.

The area covered by the *Gaultheria* colonies in each of the decennial surveys, and the estimated minimal population size that may have been present in 1868, were plotted against time, to give a graphic representation of the apparent pattern of population expansion and collapse (Figure 2).

## DISCUSSION

A change in the area covered by *Gaultheria procumbens* at Pine Hills is a function of the temporary disequilibrium of the relationship between the plant and its environment. The vigor of the population as observed in 1951 and its continued growth through 1961 is a clear measure of conditions that favored expansion of the colonies. The most apparent factor permitting this expansion was an increased light intensity following the removal in 1868 of the overlying hemlock shade. Similarly, the deterioration of the population as measured in 1971 and its collapse by 1981 is an unmistakable consequence of a change in the previous advantageous condition, in the form of a dense, light-excluding growth of young hemlocks.

The Pine Hills *Gaultheria* population between 1868, when the assumed population size was minimal, and 1961 when a total area of 307 $m^2$ was recorded, conforms to an exponential rate of increase (Figure 2). This pattern of exponential increase is familiar in situations where carrying capacity of the environment is not

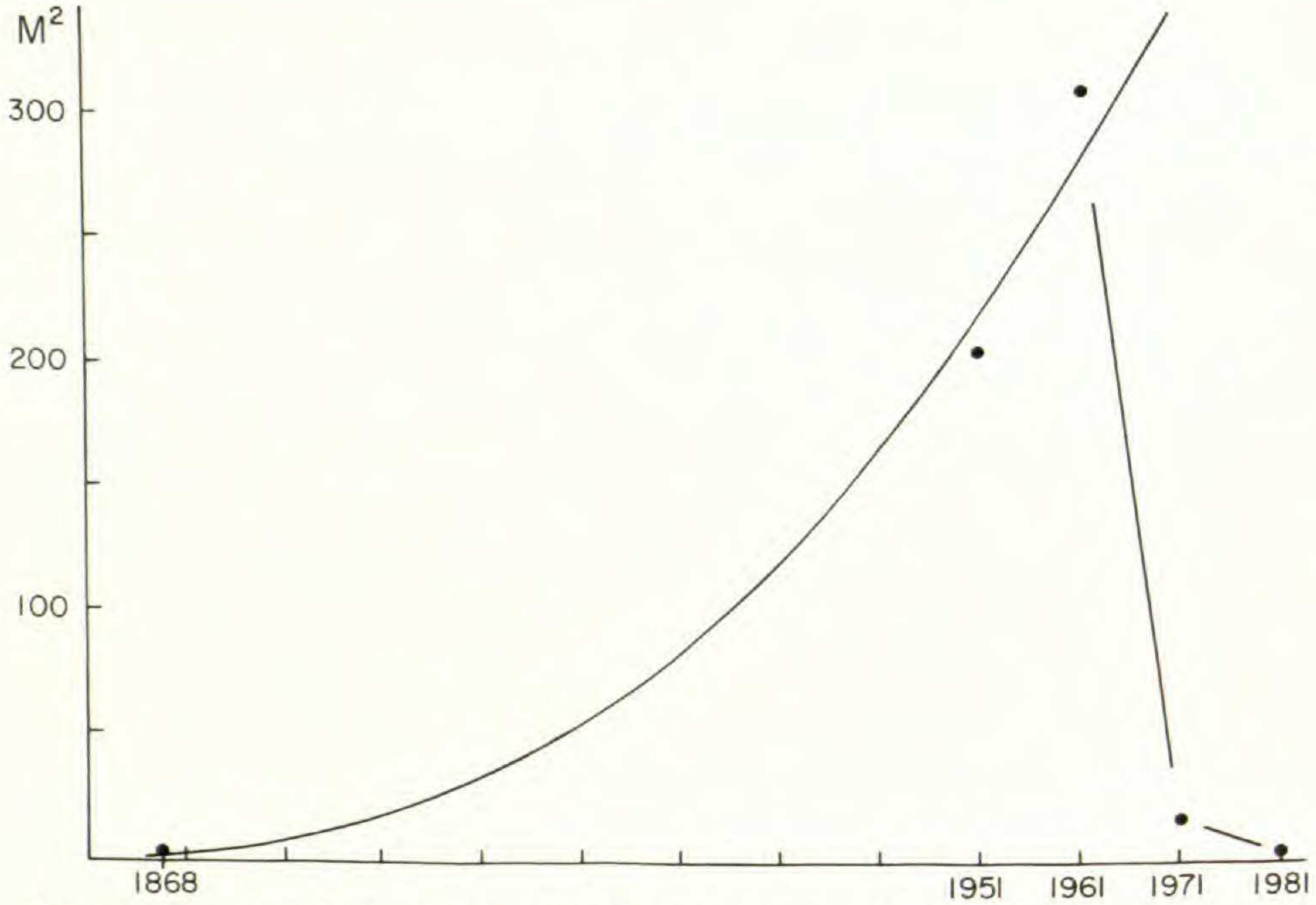


Figure 2. Growth curve showing the area occupied by *Gaultheria procumbens* colonies on the Mill Cut Backbone, Pine Hills, Indiana, in 1868 (estimated), 1951, 1961, 1971, and 1981. Change in the area of the colonies through 1961 approximates an exponential increase (line: $y = x^2$). Between 1961 and 1971, and continuing through 1981, the area of the colonies declined precipitously, to approach local extinction.

reached. There is no indication of the beginning of the familiar sigmoid curve or logistic in which factors limiting growth progressively come into play (Hutchinson, 1978; Silvertown, 1987).

The decline in population area between 1961 and 1981, though it had been foreshadowed by a thinning of stem density, was abrupt and not anticipated by observed transitional stages. The data permit only approximate straight-line indications of intermediate population size.

This pattern of vigorous growth followed by sudden collapse, without carrying capacity of the environment having been reached, is commonly experienced with populations of small short-lived organisms or organisms occupying transient habitats (Keeton, 1976), but has perhaps not previously been recorded in a population of perennial plants over an extended period of time.

The writer has examined in some detail the factors associated with the near-disappearance of *Gaultheria procumbens* from the Pine Hills area (Ward, 1976). The underlying Borden sandstone upon decomposition yields an acid soil that appears to be nec-

essary for the persistence of hemlock and white pine (Potzger and Friesner, 1937) and very possibly *Gaultheria.* The predominance of hemlock on the slopes of the various backbones of the Pine Hills, and particularly on the knolls which rise at the ends of these backbones within the loop of the encircling stream (Friesner and Potzger, 1934), together with the recent vigorous growth of hemlock on the Mill Cut knoll, at first suggested that this species is the expected climax on the wintergreen slope. The present restriction of mature hemlock to the crest of the knoll above the *Gaultheria* population was interpreted as the result of the removal in 1868 of these readily accessible, easily felled and shaped, mature trees from the lower slope, to form the log crib dam across Clifty Creek. Yet the infrequency with which *Gaultheria* is elsewhere associated with hemlock indicates that other species were surely a part of the arboreous flora.

*Gaultheria procumbens* is, as its common name clearly states, "winter green." This characteristic is presumably of value in permitting the plant to continue to photosynthesize during favorable weather in the late fall, winter, and early spring, when other species are leafless in a predominantly deciduous woodland. *Gaultheria* is not unique in this capability. In Ohio, 287 species, representing about 16% of that state's herbaceous flowering plants, have been identified as "winter-green" (Beatley, 1956).

The "winter-green" species of Ohio were found to be numerous in oak associations, while the only flowering plant observed to remain green in hemlock communities was *Mitchella repens. Gaultheria* was restricted to oak–chestnut, oak–hickory, and oak–pine associations (Beatley, 1956). In Indiana also, wintergreen is commonly associated with oak (Deam, 1940). Throughout the survey period the Mill Cut slope has supported a number of white oak, as well as a few black oak and northern red oak, some of which were estimated in 1971 to have dates of "zero diameter" of 1704, 1815, 1821, 1832, 1854, and 1858 (Ward, 1976). It thus appears probable that the slope at the time of logging in 1868 was not wholly covered with a dense stand of hemlock, but with a mixed association of hemlock and oak.

Perhaps the nearest physiographic match to the Mill Cut knoll is the ridge and slope at the east end of the adjacent ridge to the north, Turkey Backbone (Smith, 1933). The hemlock on the knoll and adjoining stream terrace of Turkey Backbone is the most extensive found in the Pine Hills area (Friesner and Potzger,

1934), and is almost without admixture of oak or other arboreous species. Yet the Turkey Backbone hemlock is growing on either level or north-facing surfaces, quite unlike the warm, sunny, south-facing *Gaultheria* slope of the Mill Cut knoll.

The *Gaultheria* population in 1868 may be appraised as consisting of no more than four isolated, marginally surviving plants, released by the abrupt removal of the shade of the hemlock overstory to expand into the four discrete colonies observed in 1951 (Ward, 1976). This supposition is supported by the observed rate of expansion of the population between 1951 and 1961. Since no point in the 1951 colonies was more than 4.9 m from the periphery, by the smaller estimate of 10 cm/year, approximately 50 years would have been sufficient for development of the largest colony. This figure has been suggested to be within permissible limits of error of the 83 years that had elapsed since construction of the dam and logging of the *Gaultheria* slope (Ward, 1976).

The decennial surveys from 1951 through 1981 were observational, and it is possible to state only by deduction the forces that were responsible for the changes in the *Gaultheria* population. Within this limitation, the post-Pleistocene history of *Gaultheria procumbens* in the Pine Hills area may be outlined. Following the last glacial recession the boreal forest again moved northward. Wintergreen was perhaps abundant, or at least sufficiently frequent to sustain populations of insect or other pollen vectors and agents of seed dissemination. With increasing climate moderation and intrusion of more temperate species, the boreal forest became restricted to limited sites of suitable soil or shade or moisture. In the Pine Hills area, though hemlock, white pine, and other boreal species were well adapted to many sites, *Gaultheria* was restricted to a niche found only on the sunny, south-facing, acidic, oak-forested slope of the Mill Cut knoll, and disappeared, or was never present, on the cooler, level terraces or north-facing slopes dominated by hemlock. Sexual reproduction ceased, perhaps through the disappearance of a pollinator, and the wintergreen colonies expanded or contracted in synchrony with fluctuations of hemlock incursion onto the south-facing slope. Perhaps windthrow of mature hemlocks on the shallow soil periodically opened the canopy and permitted expansion of the wintergreen, and subsequent regrowth of the hemlock again reduced the size and vigor of the colonies. In the mid-nineteenth century the wintergreen population was at a low level, perhaps very near local extinction. But

in 1868, by the intervention of man and his need for straight, easily felled logs for the construction of a nearby dam, the hemlock was wholly removed, leaving only a thin oak overstory beneath which the wintergreen recovered. The population thrived, by 1961 reaching a level and vigor in excess of that attained in past fluctuations. The hemlock also returned, its seeds finding a suitable bed in the dense carpets of wintergreen, and the extent of the opening caused by the removal of the mature trees providing an unprecedented absence of competition. The profuse growth of sapling hemlocks created a dense shade beneath which the wintergreen colonies ceased to expand and began to fragment. By 1981 only a few *Gaultheria* plants were to be seen, and the survival of the colony, so fortuitously prolonged by the 1868 logging, was again in peril.

## EPILOGUE

Upon completion of the 1981 survey it was abundantly apparent that the factors causing the decline in *Gaultheria* on the Mill Cut knoll would inevitably result in the local extinction of the species if left unchecked. Regrowth of the hemlock on the slope cut in 1868 was accepted as the dominant influence in this decline. Although the presence of *Gaultheria procumbens* in the northern tier of counties has precluded its classification as an endangered or threatened species in Indiana (Aldrich et al., 1986), retention of the native population of wintergreen, as a part of the Pine Hills relic flora, seemed to be of high scientific worth and well within the commitment by the State of Indiana to preserve the land and its natural resources in perpetuity.

A proposal was made to the Indiana Department of Natural Resources, custodian of Pine Hills, that the sapling hemlocks and pines be cut from a circle of 5 m radius centered on the few surviving wintergreen plants. The concept of this proposal was accepted, and in February, 1983 the small trees were removed from a 3 × 3 m square with overhanging branches trimmed from adjacent larger trees. At that date 8 plants were still present. It was anticipated that the increased light intensity would permit the continued survival and re-establishment of the population.

This expectation appears not to have been realized. In September 1988 the Department again surveyed the *Gaultheria* slope.

No plants were found. The summer of 1988 had been one of severe, almost unprecedented drought, and the Mill Cut knoll was exceptionally dry. It is to be hoped that the *Gaultheria* may have survived as bare stems among the fallen leaves and in a favorable season be able to appear again in the flora of the Pine Hills.

## ACKNOWLEDGMENTS

Thirty-plus years of tramping the Pine Hills has permitted the writer to receive companionship and help from family members and friends spanning three generations. In addition to those acknowledged previously (Ward, 1976), I wish to thank my wife, Suzanne, and my son, Gordon, for their assistance with the 1981 survey and J. A. Bacone, Indiana Department of Natural Resources, and his staff for their efforts and concern in preserving the natural resources which they hold in trust.

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